BIOLOGICAL INTEGRITY IN BOX ELDER CREEK BASED ON PERIPHYTON COMPOSITION AND COMMUNITY STRUCTURE

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SUMMARY

In early August 1999, composite periphyton samples were collected from natural substrates at 8 sites on Box Elder Creek in central Montana. Samples were collected following MDEQ standard operating procedures, processed and analyzed using standard methods for periphyton, and evaluated following modified USEPA rapid bioassessment protocols for wadeable streams.

Box Elder Creek is an intermittent "pooled channel" stream with a silty bottom. It is classified C-3 in the Montana Surface Water Quality Standards.

Box Elder Creek supported a very diverse algal flora. The non-diatom algae indicated warm, standing waters with elevated concentrations of organic nutrients. This organic loading was probably internal and natural in origin (i.e., from decaying aquatic vegetation). Nitrogen was likely the limiting nutrient in Box Elder Creek, especially in the middle and lower reaches of the study section. In reaches 003 and 004, the presence of *Chara* indicated stable soft substrates and low levels of turbidity.

The diatom assemblages of Box Elder Creek supported the findings of organic nutrient loading and nitrogen limiting conditions, the latter particularly in the lower reaches of the study section. Diatom metrics also indicated low levels of disturbance and elevated concentrations of dissolved solids.

The relatively large percentage of motile diatoms indicated moderate levels of sedimentation in all reaches except Reach 001. Moderate impairment was indicated even in the reference reach (Reach 022), which was judged to be "proper functioning" based on the good condition of the riparian habitat. This may indicate that the sedimentation index is more responsive to channel morphology and stream type than it is to riparian condition.

INTRODUCTION

This report evaluates the support of aquatic life uses, and probable causes of impairment to those uses, in Box Elder Creek in central Montana. This evaluation is part of a larger study that is being conducted by the Riparian and Wetland Research Program of The University of Montana in cooperation with the U.S. EPA, MDEQ, BLM, and private landowners. Objectives of the study are (1) to evaluate several indicators that are used to monitor grazing levels in riparian areas, and (2) to determine if there are relationships between these indicators and water quality, riparian condition, and stream function. The goal is to be able to predict water quality using grazing use level indicators in riparian areas (RWRP Website).

Evaluation of use support in this report is based on the species composition and community structure of periphyton (benthic algae) communities at 8 stream sites that were sampled in early August 1999. The periphyton or phytobenthos community is a basic biological component of all aquatic ecosystems. Periphyton accounts for much of the primary production and biological diversity of Montana streams (Bahls et al. 1992).

Plafkin et al. (1989) and Stevenson and Bahls (1999) list several advantages of using periphyton in biological assessments of streams:

- Algae are universally present in large numbers in all streams and unimpaired periphyton assemblages typically support a large number (>30) of species;

- Algae have rapid reproduction rates and short life cycles, making them useful indicators of short-term impacts;

- As primary producers, algae are most directly affected by physical and chemical factors, such as temperature, nutrients, and toxins;

- Sampling is quick, easy and inexpensive, and causes minimal damage to resident biota and their habitat;
- Standard methods and criteria exist for evaluating the composition, structure, and biomass of algal associations;
- Identification to species is straightforward for the diatoms, for which there is a large body of taxonomic and ecological literature;
- Excessive algae growth in streams is often correctly perceived as a problem by the public.
- Periphyton and other biological communities reflect the *biological integrity*[1] of waterbodies; restoring and maintaining the biological integrity of waterbodies is a goal of the federal Clean Water Act;
- Periphyton and other biological communities integrate the effects of different stressors and provide a measure of their aggregate impact; and
- Periphyton and other biological communities may be the only practical means of evaluating impacts from non-point sources of pollution where specific ambient criteria do not exist (e.g., impacts that degrade habitat or increase nutrients).

Periphyton is a diverse assortment of simple photosynthetic organisms called algae, and other microorganisms that live attached to or in close proximity of the stream bottom. Most algae, such as the diatoms, are microscopic. Diatoms are distinguished by having a cell wall composed of opaline glass--hydrated amorphous silica. Diatoms often carpet a stream bottom with a slippery brown film.

Some algae, such as the filamentous greens, are conspicuous and their excessive growth may be aesthetically displeasing, deplete dissolved oxygen, interfere with fishing and fish

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[1] *Biological integrity* is defined as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region" (Karr and Dudley 1981).

spawning, clog irrigation intakes, create tastes and odors in drinking water, and cause other problems.

The federal Clean Water Act directs states to develop water pollution control plans (Total Maximum Daily Loads or TMDLs) that set limits on pollution loading to water-quality limited waters. Water-quality limited waters are lakes and stream segments that do not meet water-quality standards, that is, that do not fully support their beneficial uses. The Clean Water Act and EPA regulations require each state to (1) identify waters that are water-quality limited, (2) prioritize and target waters for TMDLs, and (3) develop TMDL plans to attain and maintain water-quality standards for all water-quality limited waters.

One purpose of this report is to provide information that will help the State of Montana to determine whether Box Elder Creek is water-quality limited and in need of TMDLs. Another purpose of this report is to evaluate the sensitivity of periphyton metrics to grazing levels in riparian areas.

PROJECT AREA AND SAMPLING SITES

The project area is a section of Box Elder Creek north of Winnett in Petroleum County in central Montana. Box Elder Creek heads in the Judith Mountains northeast of Lewistown and flows southeasterly for about 70 miles to the point where it meets the Musselshell River upstream from Mosby, Montana. The watershed encompasses 1,184 square miles.

The project area is in the Central Grassland Subregion of the Northwestern Great Plains Ecoregion (Woods et al. 1999). The surface geology consists mainly of marine shales of the Colorado Group (Taylor and Ashley, undated). Upland vegetation in the study area is mixed grassland (USDA 1976). Riparian vegetation

along Box Elder Creek is dominated by graminoids and introduced herbaceous species. The sparse shrub layer is dominated by western snowberry, sandbar willow, peachleaf willow, and box elder (RWRP Website). The main land use is livestock grazing.

Elevations at the sampling sites range from about 2,940 feet at the upper site (Reach 022) to 2,860 feet at the lowest site (Reach 001). Box Elder Creek is an intermittent "pooled channel" stream with a silty bottom (Amy Chadwick, RWRP, personal communication). It is classified C-3 in the Montana Surface Water Quality Standards.

METHODS

Periphyton samples were collected from pool edges at 8 sites in early August 1999 (Table 1). Three replicate samples were collected at one of these sites (Reach 003). Reach 022 was considered to be a "properly functioning" reference reach from the standpoint of riparian habitat. The other reaches were rated "functional at risk" (Amy Chadwick, RWRP, pers. comm.).

Periphyton samples were collected following standard operating procedures of the MDEQ Planning, Prevention, and Assistance Division. Using appropriate tools, microalgae were scraped, brushed, or sucked from natural substrates in proportion to the rank of those substrates at the study site. Macroalgae were picked by hand in proportion to their abundance at the site. All collections of microalgae and macroalgae were pooled into a common container and preserved with Lugol's solution.

Samples were examined to estimate the relative abundance and rank by biovolume of diatoms and genera of soft (non-diatom) algae according to the method described in Bahls (1993). Soft algae were identified using Prescott (1978), Smith (1950), and

Whitford and Schumacher (1984). These books also served as the main references on the ecology of the soft algae.

After the identification of soft algae, raw periphyton samples were cleaned of organic matter using sulfuric acid, and permanent diatom slides were prepared in a high refractive index mounting medium following *Standard Methods for the Examination of Water and Wastewater* (APHA 1998). For each slide, between 437 and 496 diatom cells (874 to 992 valves) were counted at random and identified to species.

The following were used as the main taxonomic and autecological references for the diatoms: Krammer and Lange-Bertalot 1986, 1988, 1991a, 1991b; Patrick and Reimer 1966, 1975. Lowe (1974) was also used extensively as an ecological reference for the diatoms. Bahls et al. (1984) provide autecological information on important diatom species that live in the Southern Fort Union Coal Region of Montana, which includes many of those living in Box Elder Creek.

The diatom proportional counts were used to generate an array of diatom association metrics (Table 2). A metric is a characteristic of the biota that changes in some predictable way with increased human influence (Barbour et al. 1999).

One additional metric was calculated for this study: percent of cells in the diatom family Epithemiaceae. This family is represented in streams by two genera, *Epithemia* and *Rhopalodia*, that commonly harbor endosymbiotic nitrogen-fixing bluegreen algae (cyanobacteria) within their cells. A diatom association that contains a large percentage of cells in these genera may indicate nitrogen-limiting conditions, that is, low nitrogen to phosphorus ratios (Stevenson and Pan 1999).

Metric values from Box Elder Creek were compared to numeric

biocriteria developed for streams in the Great Plains Ecoregions of Montana (Table 3). These criteria are based on metric values measured in least-impaired reference streams (Bahls et al. 1992) and on metric values measured in streams that are known to be impaired by various sources and causes of pollution (Bahls 1993).

The criteria in Table 3 distinguish among four levels of impairment and three levels of aquatic life use support: no impairment or only minor impairment (full support); moderate impairment (partial support); and severe impairment (nonsupport). These impairment levels correspond to excellent, good, fair, and poor *biological integrity*, respectively.

Only periphyton samples collected in summer (June 21-September 21) can be compared with confidence to reference stream samples because metric values change seasonally and summer is the season in which reference streams and impaired streams were sampled for the purpose of biocriteria development.

Quality Assurance. Several steps were taken to assure that the study results are accurate and reproducible. Upon receipt of the samples, station and sample information were recorded in a laboratory notebook and samples were assigned a unique number compatible with the Montana Diatom Database, e.g., 1885-01. The first part of this number (1885) designates the sampling site (Box Elder Creek Reach BE022); the second part of the number (01) designates the number of periphyton samples that have been collected at this site to date for which data have been entered into the Montana Diatom Database.

Sample observations and analyses of soft (non-diatom) algae were recorded in a lab notebook along with station and sample information provided by MDEQ. A portion of the raw sample was used to make duplicate diatom slides.

On completion of the project, station information, sample information, and diatom proportional count data will be entered into the Montana Diatom Database. One set of diatom slides will be deposited in the University of Montana Herbarium in Missoula. The other set of slides will be retained by *Hannaea* in Helena.

RESULTS AND DISCUSSION

Results are presented in Tables 4 and 5, located near the end of this report following the Literature Cited section. Spreadsheets containing completed diatom proportional counts, with species pollution tolerance classes (PTC) and calculated percent abundances, are attached as Appendix A.

SAMPLE NOTES

Reach 022. This sample was very silty. Macrophytes were present. The *Cladophora* here was senescent and covered with epiphytes, which included *Oedogonium*, *Phormidium*, *Rivularia,* and *Stigeoclonium*. Free-living *Oedogonium* was also present. Only straight filaments of *Anabaena* were observed.

Reach 012. This sample was very silty. Macrophytes were present. Ostracods and amphipods were very abundant. Both coiled and straight filaments of *Anabaena* were observed.

Reach 011. Sample was very silty. Terrestrial vegetation was present in the sample. The *Phormidium* was epiphytic on filamentous algae.

Reach 008. Sample was silty, but not as silty as sample from Reach 006. Macrophytes were absent, but some terrestrial vegetation was included in the sample. At least four species of *Spirogyra* were present.

Reach 006. Sample was very silty and macrophytes were present. Both straight and coiled filaments of *Anabaena* were observed. Most diatoms were very small.

Reach 004. *Chara* appears here and in Reach 003. Sample not very silty. Only straight filaments of *Anabaena* were observed.

Reach 003.3. Sample not very silty; includes macrophytes. Straight and coiled filaments of *Anabaena* were observed.

Reach 003.2. Macrophytes present. Sample not very silty. Both straight and coiled filaments of *Anabaena* were present.

Reach 003.1. Sample contains little silt. The *Calothrix* species formed large gelatinous masses. More than one species of *Anabaena* was present.

Reach 001. Sample was silty and crammed with macrophytes. Multiple species of *Oedogonium*, *Mougeotia*, and *Cosmarium* were present, as well as straight and coiled species of *Anabaena*.

NON-DIATOM ALGAE

Box Elder Creek had a very diverse algal flora, even for a prairie stream (Table 4). [Prairie streams generally have more genera of non-diatom algae and more species of diatoms than do mountain streams (Bahls 1993).] Reach 022 supported 21 genera of non-diatom algae. The other sites supported fewer genera, but still had good taxonomic richness.

All sites supported green algae (Chlorophyta), euglenoid algae, chrysophytes (mostly diatoms), and cyanobacteria. Dinoflagellates (*Gonyaulax*) and Cryptomonads (*Rhodomonas*) were uncommon to common at some of the upper sites. Algae in these latter groups are typically planktonic and found in open water.

Filamentous green algae, mainly *Cladophora*, *Rhizoclonium*, and *Spirogyra*, dominated at most of the sites (Table 4). Cyanobacteria, mainly *Anabaena*, *Calothrix*, and *Lyngbya*, were also abundant, particularly at stations near the middle and lower end of the study section. Diatoms were very common to abundant at all sites (Table 4).

Certain genera of algae have rather specific environmental requirements and serve as good indicators of water quality. *Chara*, a green macroalga, requires soft but stable substrates and clear water; it does not do well in turbid water. *Chara* was found only in Reaches 004 and 003 (Table 4). The samples from these reaches were relatively free of silt (see Sample Notes, above).

A species of *Calothrix* (Division Cyanophyta) with filaments embedded in profuse gelatinous masses, was, like *Chara*, abundant only in the lower reaches of the study section (Table 4). This taxon may also be sensitive to turbid waters.

Cladophora is a branched filamentous green alga that grows best in cool, flowing water (15-23°C). In Box Elder Creek, *Cladophora* was found only in Reach 022 (Table 4). *Cladophora* is closely related to *Rhizoclonium*, which prefers standing and warmer waters (>23°C). *Rhizoclonium* was found at all sites, including Reach 022 (Table 4).

Euglena and its cohorts *Phacus* and *Trachelomonas* generally indicate elevated concentrations of organic nutrients. These algae were found throughout the study section (Table 4). Since livestock are not known to concentrate in or along Box Elder Creek (Amy Chadwick, RWRP, personal communication), this loading is probably internal and natural in origin (i.e., from decaying aquatic vegetation).

An abundance of nitrogen-fixing cyanobacteria probably indicates that nitrogen, rather than phosphorus, is the nutrient that is in shortest supply relative to the needs of the algae of Box Elder Creek, especially in the lower reaches of the study section. Box Elder Creek was unusual in that it supported three or more species of *Anabaena*, a planktonic and sometimes toxic cyanobacterium. The abundance of *Anabaena* and the presence of several other genera of planktonic algae (e.g., the euglenoid algae plus *Chlamydomonas*, *Dinobryon*, and *Scenedesmus*) reflect the pooled nature of the Box Elder Creek channel.

DIATOMS

The major diatom species in Box Elder Creek are somewhat to very tolerant of organic pollution and nutrient enrichment (Class 2 and 1 diatoms, respectively; Table 5). *Nitzschia palea* is a nitrogen heterotroph, meaning that it can assimilate and utilize forms of organic nitrogen. Some of these major species (e.g., *Nitzschia filiformis*, *Nitzschia reversa*, and *Synedra fasciculata*) also indicate elevated concentrations of dissolved solids.

Diatom diversity and species richness were normal for a prairie stream, with only minor impairment indicated in Reaches 004 and 003 (Table 5). The pollution index indicated minor impairment at most sites, but moderate impairment in Reaches 006 and 001. The pollution index responds mostly to organic loading (Lange-Bertalot 1979). In Box Elder Creek, this loading is probably internal and natural in origin, resulting from the fertile, intermittent nature of the stream, its pooled channel morphology, and its low frequency of flushing.

The sedimentation index, which is the percentage of motile diatoms, indicated moderate impairment at all sites except Reach 001, where only minor impairment was indicated (Table 5). The sedimentation index indicated moderate impairment even in the reference reach (Reach 022), which was judged to be "proper functioning" based on the relatively good condition of the riparian habitat here (Amy Chadwick, RWRP, pers. comm.). This may indicate that the sedimentation index is more responsive to channel morphology and stream type than it is to the condition of the riparian area.

The disturbance index was uniformly low at all sites on Box Elder Creek (Table 5). The disturbance index is based on the percent abundance of *Achnanthes minutissima*, which is a pioneer species that colonizes disturbed habitats. The relatively low numbers of this taxon indicate that Box Elder Creek supported a mature algal assemblage and that there had been little physical, chemical or biological disturbance to the periphyton in the days and weeks prior to sampling.

The dominant diatom species at each site generally accounted for less than 25% of the cells (Table 5). The only exceptions were in Reaches 006 and 003, where *Nitzschia palea* and *Nitzschia frustulum*, respectively, accounted for slightly more than a quarter of the cells. This relatively low percent dominance and

the good equitability of diatom cells among species indicated only minor impairment at these sites.

Slightly more than 1% of the diatom cells in the sample from Reach 011 were abnormal in shape (Table 5). Smaller percentages of abnormal cells were counted in Reaches 008, 006, and 003. Among the causes of teratological deformities in diatom cells are toxins and salinity. Healthy diatom assemblages typically do not have abnormal cells, except for natural monstrosities represented by post-auxospore cells (*Erstlingzelle*). In mountain streams, heavy metals may produce deformities, particularly among the Fragilariaceae (McFarland et al. 1997). The cause of the abnormal cells in Box Elder Creek is unknown.

Representatives of the diatom family Epithemiaceae were present at all of the Box Elder Creek sites (Table 5). Diatoms in this family harbor endosymbiotic nitrogen-fixing cyanobacteria within their cells and are usually most abundant where nitrogen is the limiting nutrient. The percentage of diatoms in this family peaked in Reaches 003 and 001 at the downstream end of the study section.

The similarity index indicates floristic affinities between adjacent reaches. It can be used to judge the degree of change in water quality and other variables between sites. The most dissimilar adjacent reaches were 011 and 012, followed by 012 and 022 (Table 5). In fact, reaches 022 and 001 had about as much in common, floristically, as did reaches 022 and 012. On the other hand, reaches 008 and 011 were very similar, as were reaches 001 and 003, and 003 and 004 (Table 5). The duplicate samples from Reach 003 approached 80% similarity, which is to be expected for duplicate samples from the same site (Bahls 1993).

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Table 1. Location of periphyton sampling stations on Box Elder Creek: RWRP reach identification number, sample number in the Montana Diatom Database, site elevation, legal description, and sample date. Sites are listed in order from upstream to downstream. All sites are located in USGS Hydrologic Unit 10040204 (Box Elder Creek).

Reach ID Number	Sample Number	Elevation (feet)	Legal Description	Sample Date
BE022	1885-01	2,940	T16NR26E06C	08/09/1999
BE012	1884-01	2,920	T16NR26E21A/22B	08/08/1999
BE011	1883-01	2,920	T16NR26E22C	08/08/1999
BE008	1882-01	2,900	T16NR26E26B/27A	08/08/1999
BE006	1881-01	2,900	T16NR26E35A/D	08/08/1999
BE004	1880-01	2,880	T16NR26E36CD	08/08/1999
BE003.3	1879-01	2,880	T16NR26E36DC	08/08/1999
BE003.2	1878-01	2,880	T16NR26E36DC	08/08/1999
BE003.1	1877-01	2,880	T16NR26E36DC	08/08/1999
BE001	1876-01	2,860	T15NR27E06	08/08/1999

Table 2. Diatom association metrics used to evaluate biological integrity in Montana streams: reference, range of values in Montana streams, and expected direction of metric response to increasing anthropogenic perturbation or natural stress.

Metric	Reference	Range of Values	Expected Response
Shannon Species Diversity	Bahls 1979	0.00-5.00+	Decrease[1]
Pollution Index[2]	Bahls 1993	1.00-3.00	Decrease
Siltation Index[3]	Bahls 1993	0.00-90.0+	Increase
Disturbance Index[4]	Barbour *et al.* 1999	0.00-100.0	Increase
No. Species Counted	Bahls 1979, 1993	0-100+	Decrease[1]
Percent Dominant Species	Barbour *et al.* 1999	5.0-100.0	Increase
Percent Abnormal Cells	McFarland *et al.* 1997	0.0-20.0+	Increase
Similarity Index	Whittaker 1952	0.0-80.0+	Decrease

[1] Shannon diversity and species richness may increase somewhat in naturally nutrient-poor mountain streams in response to slight to moderate increases in nutrients or sediment.

[2] This is a composite numeric expression of the pollution tolerances assigned by Lange-Bertalot (1979) to the common diatom species.

[3] Computed as the sum of the percent abundances of all species in the genera *Navicula*, *Nitzschia*, and *Surirella*. These are common genera of predominantly motile taxa that are able to maintain their positions on the substrate surface in depositional environments.

[4] Computed as the percent abundance of *Achnanthes minutissima*. This attached taxon typically dominates early successional stages of benthic diatom associations and resists chemical, physical and biological disturbances in the form of metals toxicity, substrate scour by high flows and fast currents, and grazing by macroinvertebrates.

Table 3. Criteria for rating levels of biological integrity, environmental impairment or natural stress, and aquatic life use support in wadeable **plains** streams of Montana using selected metrics for benthic diatom associations. The lowest rating for any one metric is the overall rating for the study site.

Biological Integrity/ Impairment or Natural Stress/Use Support	Diversity Index (Shannon)	Pollution Index	Siltation Index	Disturbance Index	Number of Species Counted	Percent Dominant Species	Percent Abnormal Cells	Similarity Index[1]
Excellent None/Full Support	>3.99	>2.25	<50.0	<25.0	>39	<25.0	0.0	>59.9
Good/Minor Full Support	3.00-3.99	1.76-2.25	50.0-69.9	25.0-49.9	30-39	25.0 49.9	>0.0-<1.0	40.0-59.9
Fair/Moderate Partial Support	2.00-2.99	1.25-1.75	70.0-89.9	50.0-74.9	20-29	50.0-74.9	1.0-9.9	20.0-39.9
Poor/Severe Nonsupport	<2.00	<1.25	>89.9	>74.9	<20	>74.9	>9.9	<20.0

[1] The Similarity Index or Percent Community Similarity (Whittaker 1952) may be used to compare a study site to an unimpaired upstream control site on the same stream. This metric measures the degree of floristic similarity between diatom associations at the two sites and is the sum of the smaller of the two percent abundance values for each species that is common to both sites. Adjacent riffles on the same stream, without intervening tributaries or environmental perturbations, will generally have at least 60% of their diatom floras in common (Bahls 1993). PCS may also be used to guage the relative amount of impairment or recovery that occurs between adjacent study sites: >59.9% = very similar floras, no change; 40.0-59.9% = somewhat similar floras, minor change; 20.0-39.9% = somewhat dissimilar floras, moderate change; <20.0% = very dissimilar floras, major change.

Table 4. Estimated relative abundance of algal cells and rank by volume of diatoms and genera of non-diatom algae in periphyton samples collected from Box Elder Creek in August 1999. Sites and data are listed in order from upstream to downstream, left to right. R = rare, U = uncommon, C = common, VC = very common, A = abundant, VA = very abundant.

Taxa	Reach									
	022	012	011	008	006	004	003.3	003.2	003.1	001
Chlorophyta										
Ankistrodesmus	U(16)	U(12)							R	C(11)
Bulbochaete	R					R				
Chara						C(5)	A(3)	A(2)	A(3)	
Chlamydomonas					R		A(6)	VC(6)	VC(7)	
Cladophora	VA(1)									
Closterium		U(9)	U(12)		U(8)	R				R
Cosmarium	R	R	R		R	R	R		C(9)	U(9)
Microspora	U(12)	U(8)	C(8)	U(8)	C(7)			VC(9)		C(8)
Mougeotia	R				U(9)	VA(1)	R			VA(2)
Oedogonium	A(4)	VC(4)	A(3)	A(2)	C(6)	U(10)		C(11)		VC(6)
Rhizoclonium	VA(2)	VA(1)	VA(2)	VC(5)	VA(1)	C(8)	VA(1)	VA(1)	VA(1)	VA(1)
Scenedesmus	C(13)		R	R	U(12)			R	R	R
Spirogyra	A(3)	VA(2)	VA(1)	VA(1)	VA(2)	A(2)	U(8)	VC(8)	U(10)	U(10)
Stigeoclonium	C(7)									
Euglenophyta										
Euglena	R	U(11)	U(13)	C(7)		U(9)	C(9)	VC(7)	C(8)	U(12)
Phacus		R			R					
Trachelomonas		R						R		
Chrysophyta										
Diatoms	VC(5)	A(3)	VC(5)	VC(4)	VC(4)	VC(6)	VC(7)	A(5)	A(5)	VC(5)
Dinobryon				R	U(11)					
Tribonema					U(10)					
Pyrrophyta										
Gonyaulax	U(14)	U(10)	C(11)	C(6)						R

Table 4. Continued...

Taxa	Reach									
	022	012	011	008	006	004	003.3	003.2	003.1	001
Cyanophyta										
Amphithrix	U(15)							R	R	U(13)
Anabaena	C(11)	C(6)	C(7)	U(9)	VC(5)	VC(7)	VA(2)	A(4)	A(4)	A(3)
Calothrix						A(4)	A(5)	A(3)	VA(2)	A(4)
Chroococcus										R
Coelosphaerium										R
Hydrocoleum	C(10)		C(10)							
Lyngbya		C(5)	A(4)	A(3)	VA(3)	A(3)	A(4)	C(10)	VC(6)	C(7)
Merismopedia					R		R		R	U(14)
Nodularia	C(9)		C(9)							
Oscillatoria	C(8)	C(7)		R			R			
Phormidium	C(6)	U(13)	VC(6)							
Rivularia	R									
Spirulina					R		R	R	R	
Cryptophyta										
Rhodomonas			U(14)	U(10)						

Table 5. Percent abundance of major diatom species[1] and values of selected diatom association metrics for periphyton samples collected from Box Elder Creek in August 1999. Underlined values indicate full support of aquatic life uses with minor impairment; **bold values** indicate partial support of aquatic life uses with moderate impairment; all other values indicate full support of aquatic life uses and no impairment based on the ecoregional reference stream approach (Protocol I in Bahls 1993) and criteria for wadeable prairie streams in Table 3.

Species/Metric (Pollution Tolerance Class)	Reach 022	012	011	008	006	004	003.3	003.2	003.1	001
Nitzschia filiformis (2)	2.6	13.9	1.1	0.3		p[2]				
Nitzschia frustulum (2)	14.2	7.1	18.5	16.5	10.3	24.7	25.3	20.7	23.9	20.1
Nitzschia palea (1)	18.9	8.4	10.6	16.6	29.1	16.3	19.9	14.5	22.0	23.5
Nitzschia paleacea (2)	8.7	6.8	8.9	13.5	12.4	24.1	7.2	11.1	6.4	1.8
Nitzschia reversa (2)	6.6	19.3	2.4	2.8	0.8	2.8	5.6	7.7	9.9	4.2
Synedra fasciculata (2)	2.0	5.1	7.2	3.7	3.5	3.9	6.8	9.8	4.6	11.8
Number of Cells Counted	458	457	456	490	496	460	482	470	466	437
Shannon Species Diversity	4.32	4.37	4.49	4.29	4.17	3.70	3.99	4.10	3.94	4.04
Pollution Index	1.86	1.95	1.90	1.79	**1.62**	1.83	1.80	1.83	1.76	**1.68**
Siltation Index	**78.5**	**76.9**	**73.5**	**84.2**	**76.7**	**85.3**	**77.8**	**79.1**	**85.3**	67.7
Disturbance Index	6.0	1.2	3.8	3.2	1.0	0.6	0.2	0.2	0.0	0.5
Number of Species Counted	54	54	59	60	63	55	50	50	53	55
Percent Dominant Species	18.9	19.3	18.5	16.6	29.1	24.7	25.3	20.7	23.9	23.5
Percent Abnormal Cells	0.0	0.0	**1.3**	0.8	0.6	0.0	0.0	0.2	0.0	0.0
Percent Epithemiaceae	2.6	3.2	1.8	1.5	0.6	1.8	5.8	3.8	3.6	4.0
Similarity Index[3]		52.6	51.5	72.1	59.8	61.0	70.6	79.3	78.3	71.7

[1] A major diatom species is here considered to be one that accounts for 10.0 percent or more of the diatom cells that were counted at one or more stations in a sample set.

[2] A "p" indicates that the species was observed as present during a floristic scan of the slide but was not encountered during the diatom proportional count.

[3] The similarity index between Reach 001 and Reach 022 was 52.0.

APPENDIX A: DIATOM PROPORTIONAL COUNTS

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
187601	Achnanthes minutissima	3	4	0.46
187601	Amphora coffeaeformis	1	2	0.23
187601	Amphora veneta	1	5	0.57
187601	Bacillaria paradoxa	2	0	0.00
187601	Caloneis bacillum	2	2	0.23
187601	Chaetoceros muelleri	1	1	0.11
187601	Cocconeis placentula	3	4	0.46
187601	Cyclotella meneghiniana	2	43	4.92
187601	Cymbella pusilla	1	20	2.29
187601	Diploneis puella	2	6	0.69
187601	Entomoneis paludosa	2	4	0.46
187601	Epithemia adnata	2	22	2.52
187601	Epithemia sorex	3	0	0.00
187601	Epithemia turgida	3	0	0.00
187601	Gomphonema clavatum	2	1	0.11
187601	Gomphonema parvulum	1	14	1.60
187601	Gyrosigma spencerii	2	0	0.00
187601	Mastogloia smithii	2	1	0.11
187601	Navicula capitata	2	2	0.23
187601	Navicula caterva	2	17	1.95
187601	Navicula circumtexta	1	3	0.34
187601	Navicula erifuga	2	7	0.80
187601	Navicula goersii	2	2	0.23
187601	Navicula gregaria	2	18	2.06
187601	Navicula halophila	2	2	0.23
187601	Navicula peregrina	2	3	0.34
187601	Navicula reichardtiana	2	0	0.00
187601	Navicula rhynchocephala	2	1	0.11
187601	Navicula salinicola	1	6	0.69
187601	Navicula slesvicensis	2	2	0.23
187601	Navicula tenelloides	1	2	0.23
187601	Navicula tenera	1	0	0.00
187601	Navicula vandamii	2	4	0.46
187601	Navicula veneta	1	9	1.03
187601	Nitzschia acicularis	2	6	0.69
187601	Nitzschia apiculata	2	4	0.46
187601	Nitzschia archibaldii	2	10	1.14
187601	Nitzschia aurariae	1	2	0.23
187601	Nitzschia capitellata	2	2	0.23
187601	Nitzschia dissipata	3	4	0.46
187601	Nitzschia flexa	2	0	0.00
187601	Nitzschia frustulum	2	176	20.14
187601	Nitzschia inconspicua	2	1	0.11
187601	Nitzschia levidensis	2	2	0.23
187601	Nitzschia liebetruthii	2	8	0.92
187601	Nitzschia microcephala	1	13	1.49
187601	Nitzschia palea	1	205	23.46
187601	Nitzschia paleacea	2	16	1.83
187601	Nitzschia reversa	2	37	4.23
187601	Nitzschia sigma	1	1	0.11
187601	Nitzschia sociabilis	2	18	2.06
187601	Nitzschia valdestriata	2	8	0.92
187601	Pinnularia microstauron	2	2	0.23
187601	Pleurosigma delicatulum	2	2	0.23
187601	Rhoicosphenia curvata	3	2	0.23
187601	Rhopalodia brebissonii	1	3	0.34
187601	Rhopalodia gibba	2	1	0.11
187601	Rhopalodia gibberula	2	0	0.00
187601	Rhopalodia operculata	1	9	1.03
187601	Stephanodiscus hantzschii	2	5	0.57

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
187601	Surirella brebissonii	2	1	0.11
187601	Synedra fasciculata	2	103	11.78
187601	Synedra pulchella	2	25	2.86

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
187701	Amphora libyca	3	2	0.21
187701	Amphora veneta	1	9	0.97
187701	Bacillaria paradoxa	2	0	0.00
187701	Caloneis bacillum	2	7	0.75
187701	Caloneis silicula	2	2	0.21
187701	Chaetoceros muelleri	1	1	0.11
187701	Cocconeis placentula	3	6	0.64
187701	Cyclotella meneghiniana	2	8	0.86
187701	Cylindrotheca gracilis	2	2	0.21
187701	Cymbella pusilla	1	5	0.54
187701	Diploneis puella	2	3	0.32
187701	Entomoneis paludosa	2	0	0.00
187701	Epithemia adnata	2	14	1.50
187701	Epithemia sorex	3	8	0.86
187701	Gomphonema parvulum	1	6	0.64
187701	Gyrosigma macrum	2	1	0.11
187701	Navicula capitata	2	1	0.11
187701	Navicula caterva	2	22	2.36
187701	Navicula circumtexta	1	7	0.75
187701	Navicula cuspidata	2	2	0.21
187701	Navicula erifuga	2	8	0.86
187701	Navicula goersii	2	6	0.64
187701	Navicula gregaria	2	18	1.93
187701	Navicula halophila	2	0	0.00
187701	Navicula pygmaea	2	6	0.64
187701	Navicula salinarum	1	0	0.00
187701	Navicula salinicola	1	5	0.54
187701	Navicula tenelloides	1	0	0.00
187701	Navicula tenera	1	4	0.43
187701	Navicula vandamii	2	5	0.54
187701	Navicula veneta	1	3	0.32
187701	Nitzschia acicularis	2	1	0.11
187701	Nitzschia angustatula	2	1	0.11
187701	Nitzschia apiculata	2	1	0.11
187701	Nitzschia archibaldii	2	25	2.68
187701	Nitzschia bergii	1	0	0.00
187701	Nitzschia dissipata	3	7	0.75
187701	Nitzschia frustulum	2	223	23.93
187701	Nitzschia gracilis	2	4	0.43
187701	Nitzschia inconspicua	2	3	0.32
187701	Nitzschia liebetruthii	2	36	3.86
187701	Nitzschia linearis	2	2	0.21
187701	Nitzschia microcephala	1	2	0.21
187701	Nitzschia palea	1	205	22.00
187701	Nitzschia paleacea	2	60	6.44
187701	Nitzschia pusilla	1	2	0.21
187701	Nitzschia reversa	2	92	9.87
187701	Nitzschia sigma	2	0	0.00
187701	Nitzschia sociabilis	2	30	3.22
187701	Nitzschia valdecostata	2	0	0.00
187701	Nitzschia valdestriata	2	1	0.11
187701	Pleurosigma delicatulum	2	1	0.11
187701	Rhoicosphenia curvata	3	7	0.75
187701	Rhopalodia brebissonii	1	4	0.43
187701	Rhopalodia gibba	2	4	0.43
187701	Rhopalodia operculata	1	4	0.43
187701	Stauroneis tackei	2	5	0.54
187701	Stephanodiscus hantzschii	2	1	0.11
187701	Surirella brebissonii	2	13	1.39
187701	Synedra fasciculata	2	43	4.61

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
187701	Synedra pulchella	2	3	0.32

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
187801	Achnanthes minutissima	3	2	0.21
187801	Amphora veneta	1	9	0.96
187801	Caloneis bacillum	2	7	0.74
187801	Chaetoceros muelleri	1	1	0.11
187801	Cocconeis placentula	3	11	1.17
187801	Cyclotella meneghiniana	2	4	0.43
187801	Cymbella pusilla	1	4	0.43
187801	Entomoneis alata	2	1	0.11
187801	Epithemia adnata	2	19	2.02
187801	Epithemia sorex	3	9	0.96
187801	Gomphonema parvulum	1	8	0.85
187801	Navicula capitata	2	1	0.11
187801	Navicula caterva	2	32	3.40
187801	Navicula circumtexta	1	2	0.21
187801	Navicula erifuga	2	8	0.85
187801	Navicula goersii	2	6	0.64
187801	Navicula gregaria	2	10	1.06
187801	Navicula halophila	2	5	0.53
187801	Navicula minuscula	1	2	0.21
187801	Navicula salinarum	1	4	0.43
187801	Navicula salinicola	1	10	1.06
187801	Navicula slesvicensis	2	4	0.43
187801	Navicula tenera	1	3	0.32
187801	Navicula vandamii	2	3	0.32
187801	Navicula veneta	1	4	0.43
187801	Nitzschia apiculata	2	3	0.32
187801	Nitzschia archibaldii	2	48	5.11
187801	Nitzschia aurariae	1	2	0.21
187801	Nitzschia capitellata	2	4	0.43
187801	Nitzschia dissipata	3	11	1.17
187801	Nitzschia frustulum	2	195	20.74
187801	Nitzschia levidensis	2	1	0.11
187801	Nitzschia liebetruthii	2	28	2.98
187801	Nitzschia microcephala	1	16	1.70
187801	Nitzschia palea	1	136	14.47
187801	Nitzschia paleacea	2	104	11.06
187801	Nitzschia reversa	2	72	7.66
187801	Nitzschia siliqua	2	2	0.21
187801	Nitzschia sociabilis	2	13	1.38
187801	Nitzschia valdecostata	2	2	0.21
187801	Nitzschia valdestriata	2	3	0.32
187801	Pinnularia microstauron	2	2	0.21
187801	Rhoicosphenia curvata	3	13	1.38
187801	Rhopalodia brebissonii	1	2	0.21
187801	Rhopalodia gibba	2	5	0.53
187801	Rhopalodia operculata	1	1	0.11
187801	Stauroneis tackei	2	2	0.21
187801	Surirella brebissonii	2	10	1.06
187801	Synedra fasciculata	2	92	9.79
187801	Synedra pulchella	2	3	0.32

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
187901	Achnanthes delicatula	2	3	0.31
187901	Achnanthes minutissima	3	2	0.21
187901	Amphora libyca	3	1	0.10
187901	Amphora veneta	1	3	0.31
187901	Caloneis bacillum	2	6	0.62
187901	Chaetoceros muelleri	1	2	0.21
187901	Cocconeis placentula	3	8	0.83
187901	Cyclotella atomus	2	2	0.21
187901	Cyclotella meneghiniana	2	3	0.31
187901	Cymbella pusilla	1	2	0.21
187901	Diploneis puella	2	6	0.62
187901	Entomoneis paludosa	2	2	0.21
187901	Epithemia adnata	2	22	2.28
187901	Epithemia sorex	3	26	2.70
187901	Gomphonema parvulum	1	19	1.97
187901	Gyrosigma spencerii	2	2	0.21
187901	Navicula capitata	2	4	0.41
187901	Navicula caterva	2	13	1.35
187901	Navicula circumtexta	1	7	0.73
187901	Navicula erifuga	2	7	0.73
187901	Navicula goersii	2	6	0.62
187901	Navicula gregaria	2	18	1.87
187901	Navicula omissa	1	1	0.10
187901	Navicula salinicola	1	10	1.04
187901	Navicula vandamii	2	10	1.04
187901	Navicula veneta	1	2	0.21
187901	Nitzschia apiculata	2	3	0.31
187901	Nitzschia archibaldii	2	22	2.28
187901	Nitzschia aurariae	1	4	0.41
187901	Nitzschia compressa	1	2	0.21
187901	Nitzschia dissipata	3	13	1.35
187901	Nitzschia frustulum	2	244	25.31
187901	Nitzschia liebetruthii	2	28	2.90
187901	Nitzschia microcephala	1	6	0.62
187901	Nitzschia palea	1	192	19.92
187901	Nitzschia paleacea	2	69	7.16
187901	Nitzschia perspicua	1	8	0.83
187901	Nitzschia reversa	2	54	5.60
187901	Nitzschia siliqua	2	2	0.21
187901	Nitzschia sociabilis	2	15	1.56
187901	Pinnularia microstauron	2	1	0.10
187901	Pleurosigma delicatulum	2	1	0.10
187901	Rhoicosphenia curvata	3	18	1.87
187901	Rhopalodia brebissonii	1	5	0.52
187901	Rhopalodia gibba	2	2	0.21
187901	Rhopalodia operculata	1	1	0.10
187901	Stephanodiscus hantzschii	2	2	0.21
187901	Surirella brebissonii	2	10	1.04
187901	Synedra fasciculata	2	66	6.85
187901	Synedra pulchella	2	9	0.93

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188001	Achnanthes delicatula	2	1	0.11
188001	Achnanthes minutissima	3	6	0.65
188001	Amphora veneta	1	3	0.33
188001	Bacillaria paradoxa	2	1	0.11
188001	Caloneis bacillum	2	4	0.43
188001	Chaetoceros muelleri	1	1	0.11
188001	Cocconeis placentula	3	5	0.54
188001	Cyclotella meneghiniana	2	17	1.85
188001	Cylindrotheca gracilis	2	0	0.00
188001	Cymbella pusilla	1	0	0.00
188001	Diploneis puella	2	8	0.87
188001	Entomoneis paludosa	2	3	0.33
188001	Epithemia adnata	2	2	0.22
188001	Epithemia sorex	3	9	0.98
188001	Epithemia turgida	3	1	0.11
188001	Fragilaria elliptica	2	7	0.76
188001	Navicula capitata	2	1	0.11
188001	Navicula caterva	2	16	1.74
188001	Navicula erifuga	2	2	0.22
188001	Navicula goersii	2	6	0.65
188001	Navicula gregaria	2	25	2.72
188001	Navicula halophila	2	3	0.33
188001	Navicula omissa	1	2	0.22
188001	Navicula pelliculosa	1	4	0.43
188001	Navicula radiosa	3	2	0.22
188001	Navicula salinarum	1	1	0.11
188001	Navicula salinicola	1	4	0.43
188001	Navicula tenera	1	0	0.00
188001	Navicula vandamii	2	8	0.87
188001	Navicula veneta	1	10	1.09
188001	Nitzschia acicularis	2	4	0.43
188001	Nitzschia angustatula	2	0	0.00
188001	Nitzschia apiculata	2	2	0.22
188001	Nitzschia archibaldii	2	17	1.85
188001	Nitzschia aurariae	1	2	0.22
188001	Nitzschia capitellata	2	0	0.00
188001	Nitzschia dissipata	3	8	0.87
188001	Nitzschia filiformis	2	0	0.00
188001	Nitzschia fonticola	3	2	0.22
188001	Nitzschia frustulum	2	227	24.67
188001	Nitzschia gracilis	2	10	1.09
188001	Nitzschia hungarica	2	2	0.22
188001	Nitzschia inconspicua	2	4	0.43
188001	Nitzschia liebetruthii	2	16	1.74
188001	Nitzschia microcephala	1	4	0.43
188001	Nitzschia nana	2	1	0.11
188001	Nitzschia palea	1	150	16.30
188001	Nitzschia paleacea	2	222	24.13
188001	Nitzschia reversa	2	26	2.83
188001	Nitzschia siliqua	2	0	0.00
188001	Nitzschia solita	1	2	0.22
188001	Nitzschia valdestriata	2	2	0.22
188001	Pleurosigma delicatulum	2	3	0.33
188001	Rhopalodia gibba	2	2	0.22
188001	Rhopalodia operculata	1	2	0.22
188001	Stauroneis tackei	2	6	0.65
188001	Stephanodiscus hantzschii	2	1	0.11
188001	Stephanodiscus minutulus	2	1	0.11
188001	Surirella brebissonii	2	0	0.00
188001	Synedra delicatissima	2	8	0.87

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188001	Synedra famelica	2	4	0.43
188001	Synedra fasciculata	2	36	3.91
188001	Synedra pulchella	2	0	0.00
188001	Thalassiosira pseudonana	2	4	0.43

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188101	Achnanthes delicatula	2	5	0.50
188101	Achnanthes lanceolata	2	3	0.30
188101	Achnanthes minutissima	3	10	1.01
188101	Amphora veneta	1	4	0.40
188101	Bacillaria paradoxa	2	0	0.00
188101	Caloneis bacillum	2	3	0.30
188101	Caloneis sp.	3	1	0.10
188101	Chaetoceros muelleri	1	35	3.53
188101	Cocconeis placentula	3	1	0.10
188101	Cyclotella atomus	2	1	0.10
188101	Cyclotella meneghiniana	2	34	3.43
188101	Cylindrotheca gracilis	2	2	0.20
188101	Cymbella pusilla	1	4	0.40
188101	Diatoma tenue	2	2	0.20
188101	Diploneis puella	2	6	0.60
188101	Entomoneis alata	2	0	0.00
188101	Entomoneis paludosa	2	2	0.20
188101	Epithemia adnata	2	0	0.00
188101	Epithemia sorex	3	3	0.30
188101	Fragilaria elliptica	2	40	4.03
188101	Gomphonema parvulum	1	2	0.20
188101	Gyrosigma macrum	2	3	0.30
188101	Gyrosigma spencerii	2	3	0.30
188101	Navicula capitata	2	1	0.10
188101	Navicula caterva	2	4	0.40
188101	Navicula cincta	1	1	0.10
188101	Navicula circumtexta	1	4	0.40
188101	Navicula cryptotenella	2	1	0.10
188101	Navicula erifuga	2	13	1.31
188101	Navicula goersii	2	30	3.02
188101	Navicula gregaria	2	29	2.92
188101	Navicula halophila	2	1	0.10
188101	Navicula minuscula	1	6	0.60
188101	Navicula muralis	1	18	1.81
188101	Navicula omissa	1	2	0.20
188101	Navicula pygmaea	2	0	0.00
188101	Navicula salinicola	1	7	0.71
188101	Navicula slesvicensis	2	1	0.10
188101	Navicula tenelloides	1	3	0.30
188101	Navicula tenera	1	4	0.40
188101	Navicula vandamii	2	6	0.60
188101	Navicula veneta	1	19	1.92
188101	Nitzschia angustatula	2	1	0.10
188101	Nitzschia apiculata	2	2	0.20
188101	Nitzschia archibaldii	2	24	2.42
188101	Nitzschia aurariae	1	2	0.20
188101	Nitzschia capitellata	2	8	0.81
188101	Nitzschia compressa	1	1	0.10
188101	Nitzschia dissipata	3	4	0.40
188101	Nitzschia frustulum	2	102	10.28
188101	Nitzschia gracilis	2	4	0.40
188101	Nitzschia inconspicua	2	0	0.00
188101	Nitzschia leistikowii	2	0	0.00
188101	Nitzschia levidensis	2	4	0.40
188101	Nitzschia liebetruthii	2	13	1.31
188101	Nitzschia microcephala	1	5	0.50
188101	Nitzschia palea	1	289	29.13
188101	Nitzschia paleacea	2	123	12.40
188101	Nitzschia reversa	2	8	0.81
188101	Nitzschia siliqua	2	4	0.40

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188101	Nitzschia solita	1	0	0.00
188101	Nitzschia tryblionella	2	0	0.00
188101	Nitzschia valdestriata	2	17	1.71
188101	Pleurosigma delicatulum	2	5	0.50
188101	Rhoicosphenia curvata	3	6	0.60
188101	Rhopalodia gibba	2	3	0.30
188101	Rhopalodia operculata	1	0	0.00
188101	Stauroneis tackei	2	1	0.10
188101	Stephanodiscus hantzschii	2	15	1.51
188101	Stephanodiscus minutulus	2	2	0.20
188101	Surirella brebissonii	2	0	0.00
188101	Synedra fasciculata	2	35	3.53
188101	Synedra pulchella	2	0	0.00

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188201	Achnanthes delicatula	2	0	0.00
188201	Achnanthes minutissima	3	31	3.16
188201	Amphora libyca	3	2	0.20
188201	Bacillaria paradoxa	2	1	0.10
188201	Caloneis bacillum	2	4	0.41
188201	Caloneis schumanniana	2	2	0.20
188201	Cocconeis placentula	3	1	0.10
188201	Cyclotella meneghiniana	2	0	0.00
188201	Cymatopleura solea	2	2	0.20
188201	Diploneis puella	2	4	0.41
188201	Epithemia sorex	3	6	0.61
188201	Epithemia turgida	3	1	0.10
188201	Fragilaria elliptica	2	12	1.22
188201	Gomphonema parvulum	1	23	2.35
188201	Gyrosigma macrum	2	9	0.92
188201	Gyrosigma spencerii	2	3	0.31
188201	Navicula caterva	2	16	1.63
188201	Navicula cincta	1	3	0.31
188201	Navicula circumtexta	1	6	0.61
188201	Navicula erifuga	2	17	1.73
188201	Navicula goersii	2	6	0.61
188201	Navicula gregaria	2	3	0.31
188201	Navicula halophila	2	3	0.31
188201	Navicula menisculus	2	1	0.10
188201	Navicula omissa	1	6	0.61
188201	Navicula pygmaea	2	6	0.61
188201	Navicula salinicola	1	17	1.73
188201	Navicula slesvicensis	2	2	0.20
188201	Navicula tenelloides	1	4	0.41
188201	Navicula veneta	1	26	2.65
188201	Nitzschia acicularis	2	2	0.20
188201	Nitzschia aequorea	2	70	7.14
188201	Nitzschia apiculata	2	5	0.51
188201	Nitzschia archibaldii	2	4	0.41
188201	Nitzschia capitellata	2	30	3.06
188201	Nitzschia dissipata	3	4	0.41
188201	Nitzschia filiformis	2	3	0.31
188201	Nitzschia flexoides	2	2	0.20
188201	Nitzschia frustulum	2	162	16.53
188201	Nitzschia gracilis	2	2	0.20
188201	Nitzschia hungarica	2	7	0.71
188201	Nitzschia inconspicua	2	6	0.61
188201	Nitzschia liebetruthii	2	66	6.73
188201	Nitzschia microcephala	1	4	0.41
188201	Nitzschia palea	1	163	16.63
188201	Nitzschia paleacea	2	132	13.47
188201	Nitzschia perspicua	1	2	0.20
188201	Nitzschia reversa	2	27	2.76
188201	Nitzschia sigmoidea	3	1	0.10
188201	Nitzschia siliqua	2	4	0.41
188201	Nitzschia solita	1	4	0.41
188201	Nitzschia sublinearis	2	2	0.20
188201	Nitzschia valdecostata	2	2	0.20
188201	Nitzschia valdestriata	2	4	0.41
188201	Pinnularia microstauron	2	0	0.00
188201	Pleurosigma delicatulum	2	1	0.10
188201	Rhoicosphenia curvata	3	3	0.31
188201	Rhopalodia gibba	2	8	0.82
188201	Stephanodiscus hantzschii	2	2	0.20
188201	Surirella brebissonii	2	2	0.20

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188201	Synedra delicatissima	2	1	0.10
188201	Synedra famelica	2	2	0.20
188201	Synedra fasciculata	2	36	3.67
188201	Synedra pulchella	2	0	0.00

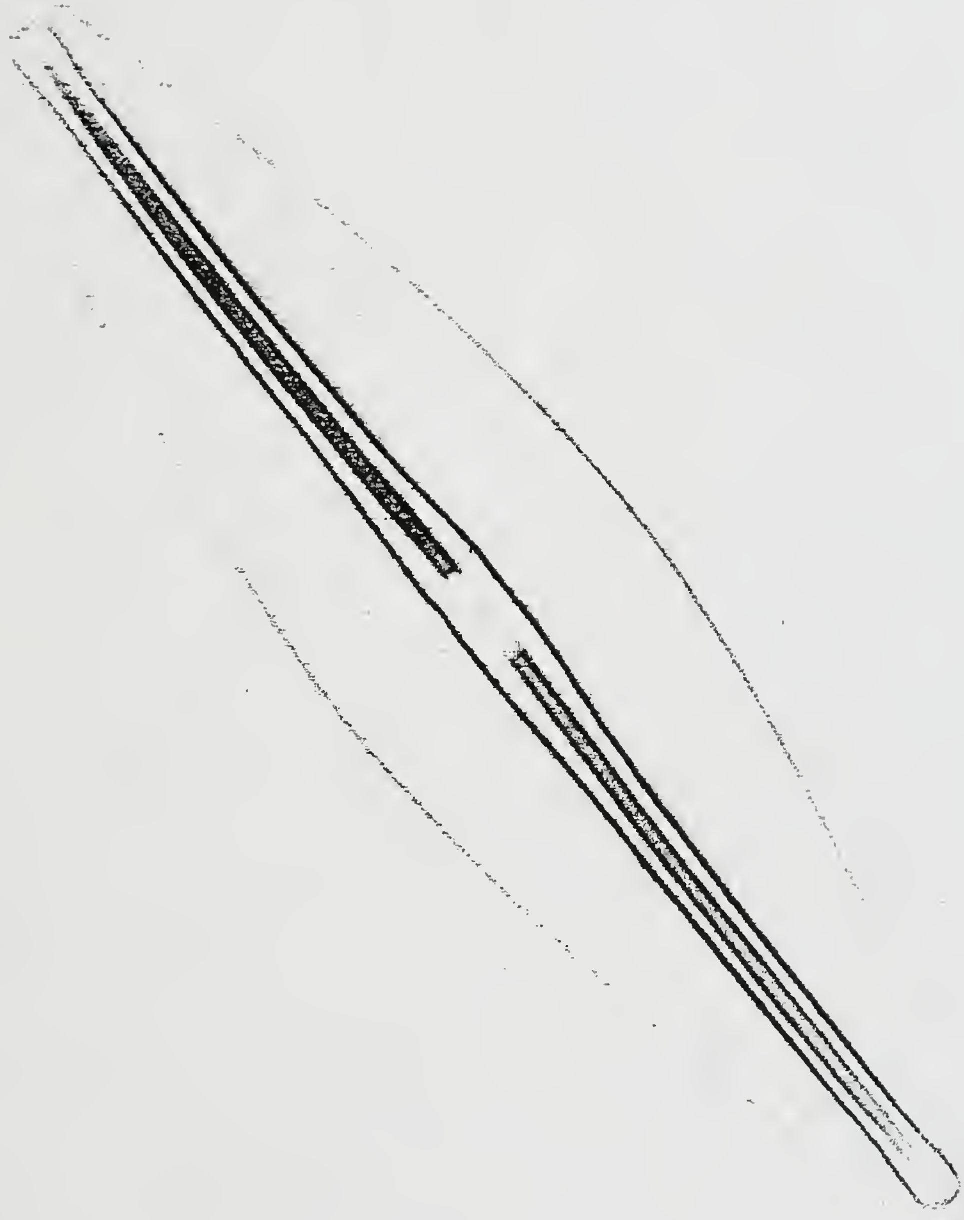
Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188301	Achnanthes delicatula	2	2	0.22
188301	Achnanthes lanceolata	2	3	0.33
188301	Achnanthes minutissima	3	35	3.84
188301	Amphora veneta	1	1	0.11
188301	Caloneis bacillum	2	14	1.54
188301	Cocconeis pediculus	3	0	0.00
188301	Cyclotella atomus	2	4	0.44
188301	Cyclotella meneghiniana	2	4	0.44
188301	Cymbella pusilla	1	1	0.11
188301	Diploneis puella	2	1	0.11
188301	Entomoneis alata	2	2	0.22
188301	Epithemia adnata	2	2	0.22
188301	Epithemia sorex	3	4	0.44
188301	Fragilaria elliptica	2	3	0.33
188301	Gomphonema clavatum	2	1	0.11
188301	Gomphonema gracile	2	2	0.22
188301	Gomphonema parvulum	1	26	2.85
188301	Gyrosigma macrum	2	19	2.08
188301	Gyrosigma spencerii	2	0	0.00
188301	Navicula capitata	2	3	0.33
188301	Navicula caterva	2	8	0.88
188301	Navicula cincta	1	3	0.33
188301	Navicula cuspidata	2	1	0.11
188301	Navicula erifuga	2	1	0.11
188301	Navicula gregaria	2	15	1.64
188301	Navicula halophila	2	4	0.44
188301	Navicula muralis	1	2	0.22
188301	Navicula salinicola	1	4	0.44
188301	Navicula tenelloides	1	8	0.88
188301	Navicula tenera	1	2	0.22
188301	Navicula veneta	1	11	1.21
188301	Nitzschia acicularis	2	2	0.22
188301	Nitzschia aequorea	2	68	7.46
188301	Nitzschia apiculata	2	3	0.33
188301	Nitzschia archibaldii	2	8	0.88
188301	Nitzschia capitellata	2	8	0.88
188301	Nitzschia debilis	2	2	0.22
188301	Nitzschia dissipata	3	10	1.10
188301	Nitzschia filiformis	2	10	1.10
188301	Nitzschia flexa	2	1	0.11
188301	Nitzschia frustulum	2	169	18.53
188301	Nitzschia gracilis	2	2	0.22
188301	Nitzschia hungarica	2	2	0.22
188301	Nitzschia incognita	2	39	4.28
188301	Nitzschia liebetruthii	2	43	4.71
188301	Nitzschia microcephala	1	4	0.44
188301	Nitzschia palea	1	97	10.64
188301	Nitzschia paleacea	2	81	8.88
188301	Nitzschia perspicua	1	2	0.22
188301	Nitzschia reversa	2	22	2.41
188301	Nitzschia siliqua	2	5	0.55
188301	Nitzschia solita	1	4	0.44
188301	Nitzschia valdecostata	2	2	0.22
188301	Nitzschia valdestriata	2	21	2.30
188301	Pinnularia microstauron	2	1	0.11
188301	Pleurosigma delicatulum	2	11	1.21
188301	Rhoicosphenia curvata	3	29	3.18
188301	Rhopalodia brebissonii	1	0	0.00
188301	Rhopalodia gibba	2	10	1.10
188301	Surirella brebissonii	2	3	0.33

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188301	Synedra fasciculata	2	66	7.24
188301	Thalassiosira pseudonana	2	1	0.11

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188401	Achnanthes lanceolata	2	2	0.22
188401	Achnanthes minutissima	3	11	1.20
188401	Amphipleura pellucida	2	1	0.11
188401	Amphora libyca	3	2	0.22
188401	Amphora pediculus	3	0	0.00
188401	Amphora veneta	1	1	0.11
188401	Bacillaria paradoxa	2	6	0.66
188401	Caloneis bacillum	2	14	1.53
188401	Cyclotella atomus	2	6	0.66
188401	Cyclotella meneghiniana	2	17	1.86
188401	Diploneis puella	2	7	0.77
188401	Entomoneis paludosa	2	1	0.11
188401	Epithemia adnata	2	1	0.11
188401	Epithemia sorex	3	3	0.33
188401	Epithemia turgida	3	0	0.00
188401	Fragilaria elliptica	2	6	0.66
188401	Gomphonema clavatum	2	2	0.22
188401	Gomphonema gracile	2	11	1.20
188401	Gomphonema parvulum	1	13	1.42
188401	Navicula caterva	2	6	0.66
188401	Navicula circumtexta	1	0	0.00
188401	Navicula erifuga	2	35	3.83
188401	Navicula gregaria	2	1	0.11
188401	Navicula halophila	2	1	0.11
188401	Navicula omissa	1	3	0.33
188401	Navicula pygmaea	2	0	0.00
188401	Navicula radiosa	3	1	0.11
188401	Navicula recens	2	0	0.00
188401	Navicula salinicola	1	6	0.66
188401	Navicula veneta	1	15	1.64
188401	Nitzschia acicularis	2	8	0.88
188401	Nitzschia aequorea	2	14	1.53
188401	Nitzschia amphibia	2	4	0.44
188401	Nitzschia apiculata	2	2	0.22
188401	Nitzschia archibaldii	2	10	1.09
188401	Nitzschia capitellata	2	2	0.22
188401	Nitzschia dissipata	3	42	4.60
188401	Nitzschia filiformis	2	127	13.89
188401	Nitzschia frustulum	2	65	7.11
188401	Nitzschia hungarica	2	8	0.88
188401	Nitzschia incognita	2	10	1.09
188401	Nitzschia inconspicua	2	3	0.33
188401	Nitzschia liebetruthii	2	17	1.86
188401	Nitzschia palea	1	77	8.42
188401	Nitzschia paleacea	2	62	6.78
188401	Nitzschia recta	3	1	0.11
188401	Nitzschia reversa	2	176	19.26
188401	Nitzschia sigmoidea	3	0	0.00
188401	Nitzschia solita	1	3	0.33
188401	Nitzschia valdestriata	2	1	0.11
188401	Pleurosigma delicatulum	2	8	0.88
188401	Rhoicosphenia curvata	3	14	1.53
188401	Rhopalodia gibba	2	20	2.19
188401	Rhopalodia operculata	1	5	0.55
188401	Simonsenia delognei	2	2	0.22
188401	Stauroneis tackei	2	1	0.11
188401	Surirella brebissonii	2	3	0.33
188401	Synedra delicatissima	2	8	0.88
188401	Synedra fasciculata	2	47	5.14
188401	Synedra pulchella	2	0	0.00

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188401	Thalassiosira weissflogii	2	2	0.22

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188501	Achnanthes delicatula	2	1	0.11
188501	Achnanthes lanceolata	2	2	0.22
188501	Achnanthes minutissima	3	55	6.00
188501	Amphora inariensis	3	4	0.44
188501	Amphora pediculus	3	14	1.53
188501	Amphora veneta	1	1	0.11
188501	Bacillaria paradoxa	2	5	0.55
188501	Caloneis bacillum	2	16	1.75
188501	Cyclotella atomus	2	0	0.00
188501	Cyclotella meneghiniana	2	3	0.33
188501	Diploneis puella	2	1	0.11
188501	Epithemia adnata	2	3	0.33
188501	Epithemia sorex	3	7	0.76
188501	Epithemia turgida	3	2	0.22
188501	Fragilaria elliptica	2	19	2.07
188501	Gomphonema intricatum	3	2	0.22
188501	Gomphonema parvulum	1	10	1.09
188501	Gyrosigma macrum	2	1	0.11
188501	Gyrosigma spencerii	2	0	0.00
188501	Mastogloia elliptica	2	0	0.00
188501	Navicula capitata	2	3	0.33
188501	Navicula caterva	2	2	0.22
188501	Navicula erifuga	2	14	1.53
188501	Navicula gregaria	2	3	0.33
188501	Navicula halophila	2	2	0.22
188501	Navicula omissa	1	6	0.66
188501	Navicula pelliculosa	1	2	0.22
188501	Navicula radiosa	3	0	0.00
188501	Navicula reichardtiana	2	2	0.22
188501	Navicula salinicola	1	28	3.06
188501	Navicula vandamii	2	2	0.22
188501	Navicula veneta	1	9	0.98
188501	Nitzschia acicularis	2	2	0.22
188501	Nitzschia aequorea	2	74	8.08
188501	Nitzschia amphibia	2	2	0.22
188501	Nitzschia apiculata	2	4	0.44
188501	Nitzschia archibaldii	2	22	2.40
188501	Nitzschia dissipata	3	11	1.20
188501	Nitzschia filiformis	2	24	2.62
188501	Nitzschia frustulum	2	130	14.19
188501	Nitzschia hungarica	2	1	0.11
188501	Nitzschia incognita	2	6	0.66
188501	Nitzschia inconspicua	2	11	1.20
188501	Nitzschia liebetruthii	2	1	0.11
188501	Nitzschia palea	1	173	18.89
188501	Nitzschia paleacea	2	80	8.73
188501	Nitzschia perminuta	3	1	0.11
188501	Nitzschia reversa	2	60	6.55
188501	Nitzschia sociabilis	2	1	0.11
188501	Nitzschia solita	1	2	0.22
188501	Nitzschia tryblionella	2	0	0.00
188501	Nitzschia valdecostata	2	9	0.98
188501	Nitzschia valdestriata	2	32	3.49
188501	Pinnularia microstauron	2	1	0.11
188501	Pleurosigma delicatulum	2	12	1.31
188501	Rhoicosphenia curvata	3	8	0.87
188501	Rhopalodia gibba	2	9	0.98
188501	Rhopalodia operculata	1	3	0.33
188501	Surirella brebissonii	2	0	0.00
188501	Synedra fasciculata	2	18	1.97



Hannaea

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March 21, 2000

Ms. Carol Endicott
Monitoring and Data Management Bureau
Montana Department of Environmental Quality
P.O. Box 200901
Helena, Montana 59620-0901

Re: Box Elder Creek and Musselshell River Periphyton Reports
DEQ Contract No. 200012

Carol,

Enclosed are my reports on Box Elder Creek and the Musselshell River, based on samples submitted by the Riparian and Wetland Research Program of The University of Montana. I talked to Amy Chadwick and she said that these were separate studies, so I did a separate report on each one.

These projects were very instructive. Box Elder Creek is an intermittent stream and the samples were collected only from pool edges. The periphyton indicated that all of the sites were moderately impaired, most frequently by siltation. Among the impaired sites was the upstream reference site--the only site where riparian habitat was in decent shape. The Musselshell River is a perennial stream and the samples were collected only from rocks in riffles. The periphyton indicated that all of the sites fully supported their aquatic life uses, whereas riparian habitat was rated as partly at risk at all sites due to sparse vegetation and exotic species.

From all of this I would conclude the following: (1) periphyton metrics are relatively insensitive to riparian condition (unless riparian condition has a measurable effect on water quality); (2) excessive sedimentation in perennial, high energy prairie streams (e.g., the Musselshell River) can be detected only by gathering a composite, multi-habitat sample from riffles, runs, and pools (per MDEQ SOPs); and (3) separate sets of biocriteria may need to be developed for perennial vs. intermittent prairie streams.

Sincerely,

Loren Bahls

Loren L. Bahls, Ph.D.
Phycologist

P.S. Thanks very much for the assessment information on prairie streams. It will be very helpful. L